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Panic disorder patients and healthy people differently identify their own heart frequency through sound

Ilaria Santoro[1], Mauro Murgia[1], Giorgia Tamburini[1], Valter Prpic[1], Fabrizio Sors[1], Alessandra Galmonte[2], and Tiziano Agostini[1]

[1]*Department of Life Sciences, University of Trieste, Italy*
[2]*Department of Neurological and Movement Sciences, University of Verona, Italy*

The ability to detect the perceptual cues related to cardiac activity is an important aspect related to the onset and maintenance of some psychopathological disorders, such as panic disorder. We tested two groups – panic disorder (PD) patients and healthy participants – in order to examine the ability to estimate participants' own heart frequency. We used an auditory identification task, based on the administration of auditory tracks representative of ecological sounds of heartbeat. Results showed that all healthy participants underestimated their own heart frequency, whereas the majority of PD patients overestimated it. This different response tendency could influence the development of psychopathologies such as panic disorder. These outcomes suggest the possible development of training for PD patients based on the use of auditory stimulation.

Keywords: Acoustic stimulation, cardiac perception, ecological sound, panic disorder.

The perceptual experience of cardiac activity has been widely studied in psychology, since the literature suggests that this activity is probably easier to detect than other physiological ones (Kollembaum, Dahme, & Kirchner 1996). Among the cues related with cardiac activity, the easiest stimulus to focus on is heartbeat, and consequently, heart frequency. In several psychopathological conditions, cardiac perception is an important factor in the onset and maintenance of unpleasant symptoms that makes dysfunctional the patients' daily life. For instance, symptoms of panic attack have a strong physical connotation, unlike anxious episodes in which patient clearly perceives their emotional nature. Indeed, during panic attacks usually panic disorder (PD) patients report a sudden increase of heart frequency, even though it does not always correspond to an actual heart frequency modification.

Corresponding author: ilaria.santoro@phd.units.it

The focus on physiological activities has been frequently used also for the development of therapeutic exercises. For instance, cognitive-behavioural therapy makes use of interoceptive exposure (Byrne, 2011) – consisting in the voluntarily exposure of patients to bodily sensation connected to the response of a fear situation (Schmidt & Trakowski, 2004) – which brings out the physical sensations of panic. In this way, the therapy tries to make the patients aware of their physiological activation and then to accustom them to the fearful cues by degrees, phasing bodily symptoms out.

Since cardiac perception has been proven to be such an important aspect in human life, different methods have been used to assess it. The most important methods used to assess cardiac perception are: the intraindividual correlation task (Pennebaker, Gonder-Frederick, Stewart, Elfman, & Skelton, 1982; Tyrer, Lee, & Alexander, 1981), the discrimination paradigm (Katkin, 1985; Whitehead, Drescher, Heiman, & Blackwell, 1977) and the mental tracking task (Schandry, 1981). In the first one, participants are asked to pay attention to their own heartbeat and to estimate how fast their heart is beating, then their estimations are usually correlated with the actual heart frequency. The second one consists in a yes/no task in which participants are asked to detect whether the onset of external stimuli having the participants' own BPM are synchronized with their own heart rhythm. Finally, the third task consists in asking the participants to mentally count their own heartbeats in a time period and to refer the estimated number of beats.

By using this last method it has been possible to identify a characteristic response tendency for several clinical populations, as infrequent panic patients, simple phobias patients, panic and non-panic disorder patients. Generally, people suffering from PD show a better average performance in this kind of task compared to control groups and to other groups of patients. However, authors found interesting results evaluating the direction of errors; indeed they found that the proportion of participants who underestimate/overestimate their own heart frequency did not significantly change among the groups of participants (Ehlers & Breuer, 1992).

Regarding this last method, we believe that mentally counting the number of heartbeats is an experience perceptually far from individuals' experience and that different results may be obtained by using other methods which evoke a more familiar experience, such as listening to heartbeat ecological sounds. Moreover, those sounds represent a perceptual stimulation which is directly related to one of the main symptoms of panic attacks – the perception of heart frequency increase. To the best of our knowledge, no study has investigated the cardiac perception of PD patients and healthy people through the identification of heartbeat ecological sounds. As proved in other physiological domains (Murgia et al., 2015), listening to ecological sounds is an effective way to make people aware of their own physiological cues, and for this reason we decided to focus on it.

Therefore, in the present study we used an auditory identification task based on the administration of auditory tracks representative of the ecological sound associated with heartbeat. As the heartbeat has a strong temporal connotation, we chose to use an acoustic stimulation, because many studies demonstrated that the auditory channel is the best way to provide temporal information. In fact, temporal perception and sensorimotor synchronization studies proved that people can discriminate and reproduce temporal intervals through the auditory channel better than through the visual channel (Grondin & Auley, 2009; Repp & Penel, 2002). Moreover, it has been proved that people can recognize other bodily aspects, such as their own biological movement, through ecological sounds (Flach, Knoblich, & Prinz, 2004; Kennel et al., 2014; Murgia, Hohmann, Galmonte, Raab, & Agostini, 2012).

Furthermore, we focused on ecological sounds of heartbeat, since listening to ecological sounds affect physiological functions more than listening to artificial sounds (Murgia et al., 2015). As a consequence, we assumed that the use of ecological sounds, rather than artificial sounds (e.g. metronome), would be the most appropriate way to convey the heartbeat information in an identification task and would render the protocol more ecological.

In order to address the above mentioned issues, we aimed to examine the ability to estimate one's own heart frequency in two groups – PD patients and healthy participants – by using an auditory identification task based on ecological sounds of heartbeat. Based on previous literature, we hypothesized that PD patients would be more accurate in identifying their own heart frequency, compared to healthy participants.

Method

Participants

Twenty-four volunteers participated in this experiment. Twelve participants were healthy people (control group) and twelve were affected by panic disorder (PD group). The control group was formed by university students (*M* = 24,4; SD =1,16 years) without a history of panic attacks or anxiety disorders. The PD group, instead, was formed by people who suffered from panic disorders (*M* =25,9; SD =1,44 years), according to the criteria of DSM V. The diagnosis was previously made by a psychologist or a psychiatrist, or before starting the experiment, by a trained expert psychologist, following the DSM interview. All participants stated that they had no hearing limitations and no cardiovascular diseases. Moreover, they reported they habitually do not use heart frequency monitoring devices and do not spontaneously control their heart frequency. All participants declared that they were not taking any psychoactive medication.

Furthermore, another healthy volunteer took part only in a preliminary phase, for the stimuli generation. Informed consent was obtained for each participant. All participants were naïve as to the purpose of the experiment.

Stimuli generation and apparatus

In order to create a database of stimuli, we first had to record the phonocardiac sound over a stethoscope and then to edit it. In the preliminary phase, we recorded the phonocardiac sound of the volunteer, and we arbitrarily decided to isolate the sound associated with the heart frequency of 60 BPM. In order to create a database ranging from 30 BPM to 120 BPM, we manipulated the sound obtained by the volunteer, by using the Goldwave 5.58 software. We first analysed the duration of each phase of the cardiac cycle (systole, rest, diastole, rest) in order to infer mathematical formulas that could maintain the proportion between the different phases (Cardiac cycle CC=60/frequency; Systole=CC*12,96%; Rest=CC*28,63%; Diastole=CC*9,76%; Rest=CC*48,65%). Applying this formulas, we could manipulate the length of all the elements that constitute a cardiac cycle and, as a consequence, we could vary its overall duration. Using this method, we were able to generate a number of ecological sounds with different frequencies (from 30 BPM to 120 BPM, with steps of 1 BPM). We decided to create a database with this range of stimuli because it is sufficient to cover most of the heart frequencies of healthy adults at rest. Furthermore, in order to record the cardiac parameters of participants, we provided them with the heart rate monitor POLAR RS400sd. We decided to use the Polar monitor – a device commonly utilized in everyday life – because it ensures a more comfortable setting for PD participants, rather than more complex physiological devices. Finally, an mp3 player Packard Bell Audiokey Premium Fm, connected with headphones Sennheiser HD515 (total harmonic distortion <0.2%) was used to administer the stimuli.

Procedure

All the participants were briefly interviewed, with the aim to investigate both the past experiences of psychological disorders, and the possible habitual use of a heart rate monitor. If a participant showed some symptoms related with psychological disorders, without having a previous diagnosis made by a psychologist or psychiatrist, then a trained expert psychologist proceeded with the DSM V interview, in order to exclude participants who did not totally meet the criteria of PD.

Before starting the experiment, we gave a stethoscope to participants and asked them to listen to their own heart rhythm at rest (for two minutes) and after one minute of moderate physical exercise (for other two minutes). We introduced the use of the stethoscope because we performed a pilot study, in which healthy participants reported difficulties in estimating their own heart frequency through sound as they had no conscious experiences of their own heartbeat. Therefore, the auscultation phase would give participants a conscious perceptual experience of their own heart frequency in different situations (e.g. at rest and after moderate exercise), and would make them aware of how ecological sounds of heartbeat vary as a function of heart frequency. After the auscultation phase we asked participants to wait in a quiet room for about 30 minutes.

Before starting the experiment, participants were asked to wear the thoracic belt of the heart rate monitor and to sit down on a reclining chair for ten minutes. In this phase participants were asked to just relax, while we recorded their heart frequency to identify the average heart frequency at rest, during that interval. The heart rate monitor was masked in order to ensure that participants could not check their heart frequency. Then, the participants were exposed to a decreasing/increasing series of auditory tracks of the database, where each track represented a heart frequency. The decreasing series of stimuli started with the presentation of an acoustic track of 20 BPM higher than their average heart frequency. The participants listened to this track for a time sufficient to decide whether heart frequency corresponded (or not) to their own. If they decided that the track was too fast, they shifted to the subsequent track, which was 1 BPM slower, and continued decreasing progressively by 1 BPM, until they identified the track that, in their opinion, corresponded to their own heart frequency (e.g. the starting stimuli BPM of a participant with an average frequency of 60 BPM would be 80, then 79, 78, 77, etc.). Vice versa, the increasing series started with an acoustic track of 20 BPM lower than their average heart frequency, and continued increasing progressively by 1 BPM (e.g. the starting stimuli BPM of a participant with an average frequency of 60 BPM would be 40, then 41, 42, 43, etc.). No information regarding the starting stimuli (e.g. 80 or 40 BPM) was provided to participants.

Participants were required to estimate their heart frequency by identifying the acoustic track that, in their opinion, was the most similar to their own actual heart frequency, in that moment. Participants were asked to progressively listen to the tracks following the predefined sequence of the stimuli (either decreasing or increasing), without going back over the tracks that they had already listened to. Participants performed the task three times in each condition (Increasing or Decreasing heart frequencies), without any kind of feedback after their performance. The presentation of the series was alternated, and counterbalanced between subjects (I-D-I-D-I-D or D-I-D-I-D-I). The dependent variable was the heart frequency identified by participants as their own.

Data analysis and results

In a preliminary analysis, we compared the average of participants' actual BPM during the experiment, by applying an *independent samples t-test* (PD vs. Control groups), and results did not show any statistical difference between the two groups. This suggests that the physiological activation of the participants of both groups during the experiment were comparable.

For data analysis we calculated the participants' accuracy, in terms of difference between the estimated (E) and the actual (A) heart frequency ($\Delta_{BPM} = E_{BPM} - A_{BPM}$), for each trial. Then, we calculated the of average Δ_{BPM} for each participant. We hypothesized that the PD group would show a better accuracy, compared to the control group. The results only apparently confirmed our hypothesis. We compared the average Δ_{BPM} of the two groups by applying an *independent samples t-test*, and data indicated that the PD group (M = –0.1; SD = 4.89) was significantly more accurate than the control group (M = –3.49; SD = 1.93) ($t_{(22)}$ = 2.22; $p < 0.05$; d = 0.91).

However, the above mentioned result may be misleading, since it did not consider the absolute value of Δ_{BPM}. Indeed, we replicated the analysis on absolute values and the significance disappeared ($M_{control}$ = 3.49; $SD_{control}$ = 1.93; M_{PD} = 3.71; SD_{PD} = 3.12; $t_{(22)}$ = -.231). These apparently contradictory results were probably due to the different response tendency exhibited by the two groups. Indeed, if we focus on the individual performances, we can see that only the 42% of PD patients (5 out of 12) underestimated their heart frequency, while all participants in the control group underestimated it (Figure 1).

In order to check for statistically significant differences in the direction of the estimation of heart frequency in the two groups, we calculated the number of participants who over-/underestimated their own heart frequency and we applied a Fischer's exact test. Data proved that the response direction of PD and control participants significantly differed (p=0.002), suggesting that the two groups have a different tendency in heart frequency estimation.

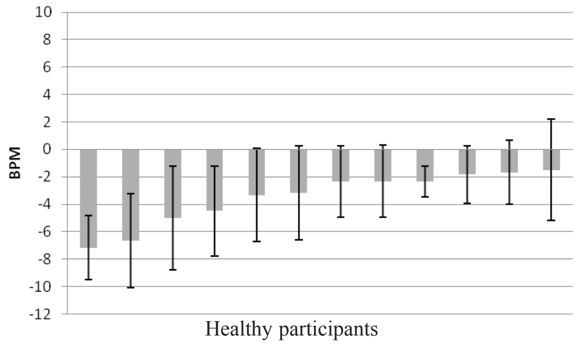

Fig 1.a

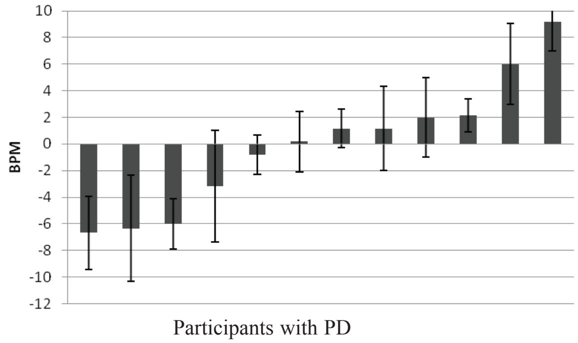

Fig 1.b

Figure 1. Description of Δ_{BPM} among all participants in both Control group (a) and PD group (b). Error bars show standard errors

Discussion and conclusion

The aim of the present study was to examine the ability to estimate one's own heart frequency in PD patients and healthy participants, by using an auditory identification task based on ecological sounds of heartbeat. We hypothesized that PD patients would be more accurate in identifying their own heart frequency, compared to healthy participants. The results only apparently confirmed our hypothesis, since the average Δ_{BPM} significantly differed between the two groups. However, a deeper analysis on absolute values of Δ_{BPM} did not reveal statistically significant differences. We decided to performe the analysis also on absolute values, since they could provide further important information on groups performances. Indeed, while the average Δ_{BPM} suggested a more accurate heart frequency identification for the PD group compared to the control group, the absolute values highlighted that the cause of this result is due to the particular response tendency of PD patients, presenting both underestimate and overestimation of heart frequency, which in turn resulted in an average accurate identification.

Surprisingly, we found a different response tendency in the two groups, in contrast with previous findings (Ehlers & Breuer, 1992). Indeed, while all participants of the control group underestimated their actual heart frequency, we found that only the 42% of the PD patients underestimated it.

The underestimation of heart frequency in healthy participants could be interpreted as a protective factor: Perceiving a heart rhythm slower than the actual one could reassure people in a stressful situation during which a natural increase in heart frequency occurs, avoiding the onset of anxious and panic symptoms. Instead, over the 50% of our PD patients would lack of this protective factor and, consequently, this would contribute to the maintenance of their pathological status. Indeed, the overestimation of heart frequency could expose PD patients to a higher risk in the development of panic episodes. In other words, PD patients would immediately focus on changes on cardiac rhythm, but they would misinterpret such changes, not being able to maintain an adequate cardiac awareness during the onset of the panic attack.

It is important to note that even a daily stressful situation (in which a natural heart frequency increase occurs) could be the triggering event of the attack panic when heart rate is overestimated. It could be interesting to investigate whether the different response tendencies occur even during stressful situations or with accelerated heart frequencies. Indeed, this investigation could provide further information regarding cardiac identification of PD patients and healthy participants, supporting or disconfirming the interpretation of the protective factor.

However, it is interesting to note that there are people suffering from PD that underestimate their own heart frequency. This evidence indicates that even people having the above mentioned protective factor may be affected by panic disorder, suggesting that it can be only one of the factors influencing the development of the psychopathology. Therefore, further research is necessary to better investigate the factors causing PD in the particular sample of patients that underestimate their own heart frequency.

It is noteworthy that the two groups did not differ from each other regarding the average BPM during the experiment. This means that PD patients did not have a higher heart frequency compared to control subjects, contradicting the idea that PD patients generally have a faster heart rhythm due to their anxious traits. Instead, our research study is in line with the findings of Pittig and colleagues (Pittig, Arch, Lam, & Craske, 2013), showing that people suffering from PD have the same average BPM of control people in a rest situation. Therefore, the increase in heart frequency appears only in some particular conditions – like panic episodes – but it cannot be considered as a specific trait of PD patients.

From a methodological perspective, an innovative point of our study consists in using an auditory identification task based on cardiac ecological sounds. However, in a future study it would be interesting to test whether the administration of artificial sounds representative of heartbeat can be comparable to that of ecological sounds, in the same auditory identification task. In this way we could test the efficacy of ecological sounds in enhancing the awareness of physiological cues, as predicted by Murgia and colleagues (2015), compared to that of artificial sounds, and we could extend their results also in the domain of cardiac activity. The extension of the results of Murgia and colleagues to the cardiac domain would have important implications in the clinical field, for the development of training strategies based on the administration of proper (artificial or ecological) sounds. Furthermore, future studies should overcome some limitations of the present work. Indeed, we missed to correlate the severity of PD patients with their heart frequency identification performance, and we tested a quite small sample, due to difficulties to recruit participants for the PD group. Therefore, next steps in research should be aimed at considering if (and how) the heart frequency identification varies according to the PD severity scores, and should test a wider sample to increase the external validity of the present results.

Moreover, a second innovative point of the present study consists in the control of the perceptual experience of participants. In fact, the use of the stethoscope allowed all participants to directly experience their own heartbeat in different situations, coping with the difficulties that healthy participants reported during our pilot experiment. Although the perceptual experience provided by the stethoscope was temporally limited, it contextually aligned the heartbeat experience of both groups, controlling for the possible confounding effect of previous heartbeat experience.

From an applied perspective, the particular response tendency shown by the PD group could be an interesting aspect for the cognitive-behavioural approach, as it could be an innovative cue on which develop the clinical treatment, supporting more typical interventions as the interoceptive exposure (Byrne et al., 2011; Schmidt & Trakowski, 2004). Indeed, while interoceptive exposure focuses on the bodily sensations associated with fear situation, working with daily bodily sensations at rest could further enhance patients' awareness regarding their own cardiac activity. The specific cardiac-perceptual tendency of the PD patients and their characteristic interpretation of physiological cues could suggest the development of a perceptual training aimed to guide people to the creation of adequate mental schemes regarding their heart frequency. The innovative aspect of this training will be the administration of auditory tracks representative of the ecological sounds associated with patients' heart frequency at rest, enhancing the identification of the auditory tracks as their own actual heart frequency and, consequently, improving their cardiac awareness. The use of the ecological sound of heartbeat would act on cardiac awareness and, consequently, would avoid that the training works as a "checking behavior".

Concluding, the present study addressed how PD patients and healthy participants identify their own heart frequency through sound. Previous studies suggested that PD patients are more accurate in cardiac perception tasks, compared to healthy people. By using an auditory identification task based on the ecological sound of heartbeat, we demonstrated that PD patients are not more accurate than healthy participants. However, we highlighted that all the healthy participants tended to underestimate their own heart frequency, whereas the majority of PD patients tended to overestimate it, reflecting different mechanisms or strategies used by theparticipants of the two populations.

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